RESTRICTED CIRCULATION

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AGRICULTURAL MEMORANDUM NO 817

Some Meteorological aspects of damage to sugar beet by the Pygmy Beetle (Atomaria linearis)

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Life Cycle

Adult pygmy beetles overwinter, without diapause, in the soil of old beet fields at depths varying from surface to about 1 metre but with the majority between 30 and 60 cm. Most beetles return to the surface in January and move about the surface when temperatures exceed about 4°C. Short flights occur when air temperatures reach about 12°C but mass dispersal flights do not take place until temperatures rise above about 18°C.

Eggs are laid in the soil around new beet plants from April onwards and development, as far as can be assessed from laboratory or greenhouse experiments, takes some 2 to 2½ months. Oviposition is protracted and may extend over some 5 months so that generations overlap. It seems probable that there will be two generations in most years with adult beetles living some 3 to 6 months. A third generation is possible in some years if spring conditions lead to an early start to oviposition and this may lead to overwintering of immature stages to emerge in the following spring.

Damage to Plants

The beetles start to feed in spring, possibly as early as March, and continue well into the summer. Most feeding is at or below the surface but also above ground in moist conditions. Feeding on the stem of newly germinated or emerging seedlings may result in the death of the plant. Once beyond the cotyledon stage the plants usually survive beetle attacks but some may be deformed and produce misshapen roots. Damage, to foliage by beetles feeding on still folded leaves at the centre of the plant, and by larvae feeding on the roots is of no great importance. Widespread, severe damage to crops would appear to require a large autumn population of beetles with a high winter survival leading to a large spring population which is active in the new beet fields at or soon after drilling. Dispersal flights from the old beet fields must be random in character since, even if the beetle had control over direction of flight, there is no new crop to attract the insect; this reinforces the requirement for a large over-wintered population so that sufficient numbers alight on the new beet fields to cause the damage. Late winter and spring conditions must be such as to induce an early return to the surface and to permit at least limited flights before crop emergence.

Damage Index

A national damage index has been devised by W H Thornhill of Broom's Barn in the form:-

$$I = \text{acres failed} + \frac{\text{acres SEVERELY damaged}}{10} + \frac{\text{acres moderately damaged}}{100} + \frac{\text{acres slightly damaged}}{1000}$$

This index has been evaluated for the years 1947 to 76 and shows a variation from less than 5 to over 500. (see Figure 1). Marked peaks occur in 1960 and 68 with lesser peaks in 1965 and 1970.

The most seriously affected area was around the Wash but no data on either spatial variation in damage or on beetle numbers was available.

Over the period studied, the number of acres failed ranged from nil to over 300 while acres slightly damaged varied from 15 to over 50,000. The relationship between the four components of the index was not constant and a particular value of the index may have resulted from a concentration of beetles causing a great deal of dmage in a particular locality or a larger population, more widely dispersed causing moderate damage over a very large area.

Data and Analysis

Because of the year to year variation in the composition of the index, a detailed study using local meteorological data could not be attempted. Departures from average of air and earth temperatures, rainfall and sunshine for East England (MWR Table 1) were extracted for 1958-76 and a preliminary examination showed a fairly consistent relationship ($r = 0.76$) between the index and the departure of the July and August 30 cm earth temperatures in the previous summer - a warm summer apparently leading to increased damage the following spring. It was necessary to assume that damage is proportional to the number of beetles although it must be admitted that a given level of damage may be caused by a small number of very active beetles or a larger number of more lethargic insects. Nevertheless it is probable that both numbers of beetles and level of activity are functions of temperature and the 30 cm earth temperatures would be a reasonable indicator of the total effect of air and soil temperatures over a period.

Total sugar beet acreage in the severely affected area increased from about 120 thousand acres in 1947 to almost 200 thousand acres in 1976. The damage index was reduced to a proportion per 100,000 acres to allow for this increase and an angular transformation $I' = \arcsin\sqrt{\text{proportion}}$ made.

Multiple regression analysis of the transformed index against 30 cm departures (0.1°C) for July to April from 1958-9 to 1973-4 gave correlation and partial regression coefficients:-

	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr
r	0.72	0.77	0.39	0.21	-0.21	0.42	0.26	0.06	0.11	0.19
b	0.47	0.96	-0.59	0.31	-0.23	0.59	-0.39	0.33	-0.63	0.43

The multiple correlation coefficient was 0.9089.

To simplify further analysis the temperature data were combined to produce autumn (A) winter (W) and spring (S) factors such that:-

$$A = 5 \times \text{Jul} + 10 \times \text{Aug} - 6 \times \text{Sep} + 3 \times \text{Oct}$$

$$W = -2 \times \text{Nov} + 6 \times \text{Dec} - 4 \times \text{Jan} + 3 \times \text{Feb}$$

$$S = -6 \times \text{Mar} + 4 \times \text{Apr}$$

Multiple regression then gave

$$I' = 18.892 + 0.096A + 0.01W + 0.102S \quad \ldots\ldots\ldots\ldots (1)$$

With multiple correlation coefficient = 0.9093.

Partial correlation coefficients were 0.8993 on A, 0.7222 on W and 0.6647 on S.

It was possible to improve the estimate slightly by including in the analysis the index for the previous year (I_{-1}) as a possible indicator of starting population and the 50% drilling date (D). Early drilling appeared to be associated with high values of the index although this may simply be a result of a mild dry spring being favourable for early sowing as well as inducing early surface activity by the beetles. The result of multiple regression analysis was then:-

$$I' = 19.862 + 0.097A + 0.095W + 0.113S - 0.171D + 0.013\ I'_{-1} \quad \ldots\ldots\ldots (2)$$

with R = 0.9154.

The partial correlations of A, W and S suggested that useful preliminary estimates of probable damage could be made in November and March from:-

$$I' = 18.492 + 0.088A \text{ in November} \quad \ldots\ldots\ldots (3)$$

$$I' = 18.304 + 0.088A + 0.035W \text{ in March} \quad \ldots\ldots\ldots (4)$$

Observed values of the index and those estimated from equations 1, 2, 3 and 4 are:-

		Estimates based on equation:-			
Year	I	3	4	1	2
1959	54.2	33.7	44.4	51.8	45.4
60	347.4	273.3	293.4	307.4	298.5
61	63.6	23.9	41.3	57.3	51.5
62	57.8	7.4	6.2	44.5	50.4
63	17.6	14.0	3.5	9.9	6.0
64	7.4	21.2	13.4	10.4	8.5
65	73.9	86.3	80.1	125.3	136.1
66	2.4	15.8	31.1	15.8	12.1
67	8.9	29.3	42.9	14.3	13.8
68	252.0	160.2	159.6	179.5	201.6
69	1.8	38.8	16.4	7.6	9.5
70	130.6	196.6	160.0	154.2	131.0
71	126.7	59.3	68.1	70.4	72.4
72	72.6	120.8	145.1	164.2	168.5
73	81.3	43.1	55.1	30.2	39.2
74	12.3	63.7	47.4	11.1	14.8
75	5.3	31.5	41.9	41.5	12.3
76	127.3	319.5	273.6	224.6	264.6

The index for the years 1948-58 appear to belong to a different regime, whether because of different husbandry, less efficient diagnosis of the cause of damage or some other cause is not known. These values can still, however, be estimated from an equation

$$I' = 5.204 + 0.013A + 0.043\ W - 0.005S - 0.094D + 0.454I'_{-1} \quad \ldots\ldots (5)$$

with R = 0.9048.

Values of the (detransformed) index observed, and estimated from equations 2 and 5 are shown in Figure 1.

Any comments or suggestions on this paper should be referred to the author.

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September 1977

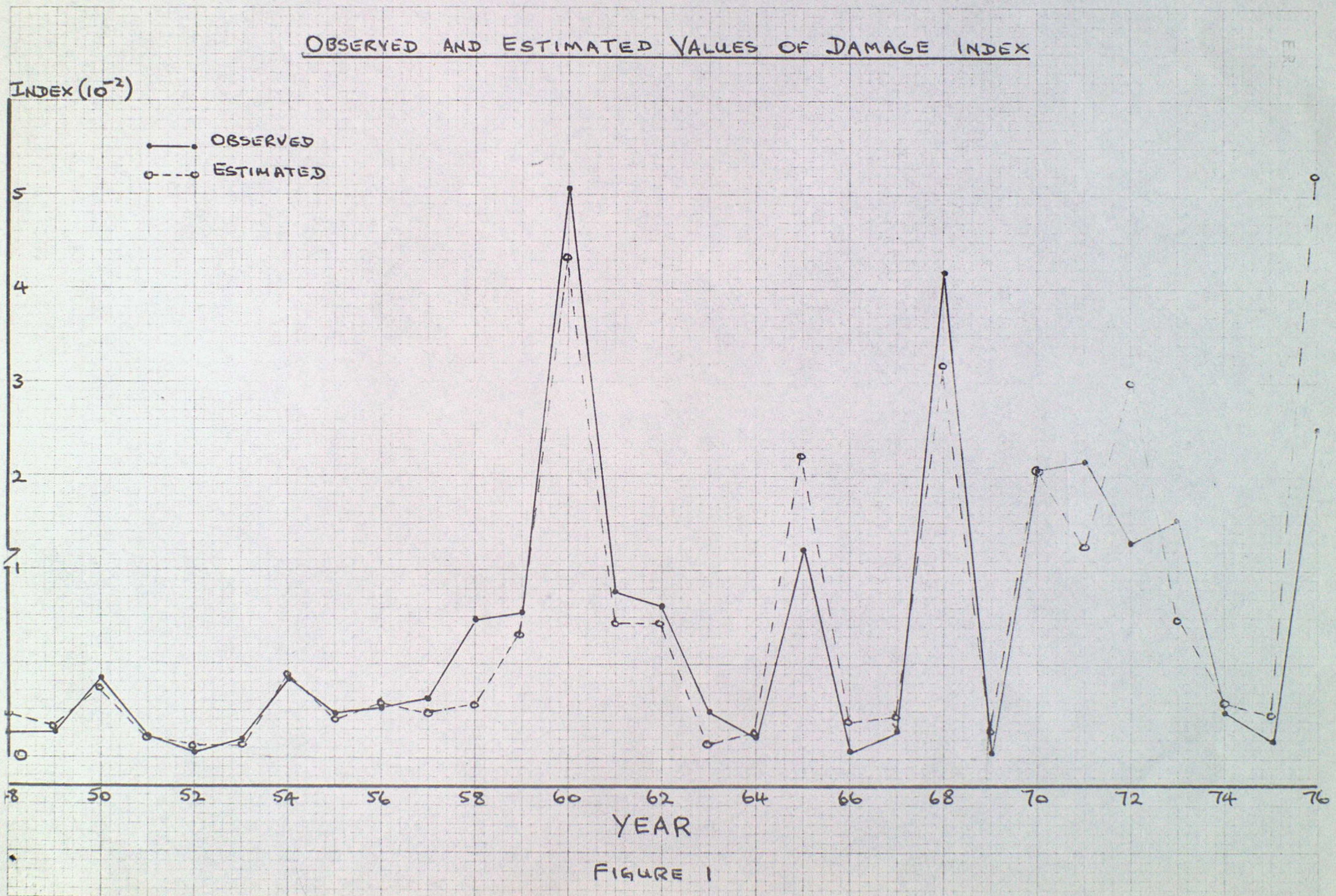
OBSERVED AND ESTIMATED VALUES OF DAMAGE INDEX
INDEX (10^{-2})
OBSERVED
ESTIMATED
5
4
3
2
1
0
48
50
52
54
56
58
60
62
64
66
68
70
72
74
76
YEAR

FIGURE 1